Application and Nursing Effects of Ultrasonic Drug Delivery Combined with Photon Therapy in Diabetic Foot Ulcers

Chen Hao, Chen Peng

The First Affiliated Hospital of Wenzhou Medical University, Wenzhou, Zhejiang, China

Abstract: To explore the application and nursing effect of ultrasound drug delivery combined with photon therapy in diabetic foot ulcers. Methods Sixty-four patients with diabetic foot ulcers admitted to a tertiary hospital in Wenzhou from December 2025 to May 2026 were selected as the research subjects. They were divided into the control group and the observation group by the random number table method. The control group was treated with photon therapy, while the observation group was treated with photon therapy combined with ultrasound drug delivery. The indicators such as the length of hospital stay, hospitalization cost, pain score, duration of antibiotic use and total effective rate of treatment were compared between the two groups. Results The length of hospital stay in the observation group was shorter than that in the control group. The hospitalization cost, pain score and antibiotic usage time in the observation group were all lower than those in the control group ($P<0.05$), and the therapeutic effect was better than that in the control group ($P<0.05$). Conclusion Ultrasound drug delivery combined with photon therapy can effectively promote the healing of diabetic foot ulcers, relieve patients' pain, reduce the use of antibiotics, shorten the length of hospital stay and lower hospitalization costs at the same time, and has good clinical application value.

Keywords: Ultrasonic Drug Introduction; Photon Therapy; Diabetic Foot Ulcer; Wound Healing; Pain Management

Diabetic foot ulcer (DFU) [1] is a common and severe complication of diabetes.Patients frequently feel pain because of the combination of neuropathy and ischemia.As the condition develops, the foot tissues gradually ulcerate, become infected, and undergo necrosis.The disease course is long and healing is difficult, which places a lot of burden on both patients and society.Topical drug therapy [2] is a key approach in DFU management, but conventional administration methods usually don't work well because there are limitations like poor blood supply to the wound site and poor drug penetration.But its effectiveness in controlling deep tissue infections is limited, and it has analgesic effects, but the treatment duration is long.Ultrasound drug delivery technology employs the mechanical, thermal, and cavitation effects of ultrasound to improve skin permeability, enable targeted drug penetration into deep tissues, and raise local drug concentration, thus achieving pain relief, anti-inflammatory effects, and tissue repair promotion[3].Therefore, this study combines photon therapy with ultrasound-guided drug delivery to assess the impact of this combined intervention wound healing in diabetic foot ulcers (DFU) patients, to provide theoretical and practical evidence for optimizing comprehensive DFU treatment protocols in clinical practice [4].

1. Subjects and Methods

1.1 Study Subjects

A total of 64 patients with diabetic foot ulcers were admitted to a tertiary Grade A hospital in Wenzhou from December 2025 to May 2026, and these were selected as study subjects.They were randomly divided into a control group (n=32) and an observation group (n=32) using a random number table.The control group was given photon therapy, and the observation group received photon therapy plus ultrasonic drug delivery.Inclusion criteria: 1.Age≥18years; 2.Meet the clinical diagnostic criteria for diabetic foot, as specified in the "China Guidelines for Diagnosis and Treatment of Diabetic Foot"[5]; 3.Diabetic foot with Wagner grade 2-4 and Rutherford grade 5 or below; 4.Ankle-brachial index (ABI) <0.9; 5.Informed consent was obtained by the patient or their family member, which was signed by them.

1.2 Treatment Methods

Both groups of patients received the standard DFU rehabilitation protocol, which included comprehensive treatments such as improving microcirculation, neurotrophic support, and promoting neural metabolism. Antibiotics were selected and dynamically adjusted based on bacterial culture and susceptibility results from wound secretions. Blood glucose levels were strictly controlled, and psychological care along with health education were enhanced. Aseptic techniques were rigorously adhered to, and necrotic tissue from the wounds was promptly removed. For pain management, the NRS pain scale was regularly used to assess pain intensity, and analgesics were administered as prescribed based on the scores. Non-pharmacological interventions such as psychological counseling and position adjustments were combined to alleviate pain and discomfort and improve treatment adherence.

1.2.1 Control Group: Photon therapy was administered.A photon therapy device (model Carnation-86s) was used to irradiate the wound surface, using continuous output modes of blue light (460 nm) and red light (640 nm)) for 20 minutes per session, with five energy levels available, administered1-2 times daily.Key nursing considerations: 1.Provide detailed explanations to the patient and their family about the purpose and precautions;2.Assess the patient's temperature sensation; if it's diminished, have the patient's family member or healthcare provider monitor the area to prevent phothermal injury. 3.Lower the bed curtain during treatment, apply a protective eye mask to the patient, keeping the irradiation distance at 10 - 15 cm from the wound; 4.Monitor the patient's vital signs and skin condition closely during irradiation; 5.Immediately terminate the treatment and notify healthcare providers if symptoms like pruritus, swelling, erythema, macules, or blisters appear at the irradiation site during or after treatment, or if photoxic reactions are observed.

1.2.2 Observation Group: In addition to the control group, ultrasound-assisted drug delivery therapy was concurrently administered.A low-frequency ultrasound drug delivery system (Model GHCS-III) was used to deliver medications by combing low-frequency ultrasound with electrical conduction.Electrode pads of size 2 were combined with medicinal agents like winter melon extract for local swelling, hematoma, pain, and anti-inflammatory effects.Parameter settings: The frequency is 1 MHz, sound intensity is 0.5 - 1.0 W/cm², each treatment session is 30 minutes, and it's administered once daily for 3 - 5 consecutive days as one treatment course.The medication was applied to the wound surface, which was located between the ultrasound probe and the wound.Key nursing considerations: 1.Before treatment, explain the purpose and precautions to the patient, and assess for any contraindications or local skin conditions. 2.During treatment, closely monitor the patient's response and ask about any discomfort;3.After the treatment, observe the changes in the wound and record the drug response; 4.Instruct the patient to keep the wound surface clean and dry, and avoid pressure.

1.3 Evaluation Indicators

Evaluation Indicators The two groups were compared on the basis of hospitalization duration, hospitalization costs, preoperatively and postoperatively pain scores.

1.3.1 Pain Rating [6]: The NRS pain scale was employed, with pain intensity scored on a 0-10 scale: 0 indicates no pain, 1-3 indicate mild pain, 4-6 indicate moderate pain, and 7-10 indicate severe pain.

1.3.2 Treatment Efficacy[7]: Markedly effective refers to the complete resolution of patients 'subjective symptoms post-intervention, with wound healing coverage exceeding 80% and a two-level reduction in lesion grading; effective indicates significant improvement in patients' subjective symptoms post-intervention, with wound healing coverage ranging from 50% to 80% and a one-level reduction in lesion grading; ineffective denotes failure to meet the aforementioned criteria or worsening of the condition.

1.4 Statistical Methods

Statistical analysis was performed using SPSS 26.0 software.Normal-distributed measurement data are expressed as $\bar{x}\pm s$.Comparisons between groups were conducted using the t-test; categorical data were presented as frequencies, and comparisons between groups were performed using the x^2 test. $P<0.05$ was considered statistically significant.

2. Results

2.1 Comparison of Baseline Characteristics Between the Two Groups

No statistically significant differences were observed in baseline characteristics such as age, gender, Wagner classification, or DFU classification between the two patient groups (P>0.05), indicating comparability, as shown in Table 1.

Table1. Comparison of General Demographic Characteristics Between the Two Patient Groups

group	age ($\bar{x}$±*s*, years)	sex (n)		Wagner grading (n)			DFU classify	
		man	woman	Level 2	Level 3	Leve l 4	ischemia	mixing
Control group (n=32)	72.53±11.19	19	13	7	19	6	26	6
Observation group (n=32)	69.41±12.54	25	7	13	10	9	22	10
t/(2	1.051	2.618		5.193			1.333	
P	0.297	0.106		0.075			0.248	

2.2 Comparison of Antibiotic Administration Duration Between the Two Groups

The observation group exhibited shorter antibiotic usage durations compared to the control group, with a statistically significant difference (P<0.05; see Table 2).

Table2. Comparison of Antibiotic Administration Durations x Between the Two Groups ($\bar{x}$±*s*)

group	duration of antibiotic use (days)
Control group (n=32)	14.63±10.50
Observation group (n=32)	8.25±4.51
t	3.156
P	0.002

2.3 Comparison of Pain Scores Between the Two Groups

No statistically significant differences were observed in pain scores between the two groups before surgery and at 12 hours postoperatively (P>0.05). The observation group exhibited significantly lower pain scores at 24 hours, 48 hours, and 72 hours postoperatively compared to the control group, with statistically significant differences (P<0.05), as shown in Table 3.

Table 3.Comparison of Pain Scores Between the Two Groups (points, $\bar{x}$±*s*)

group	Preoperative	12 hours postoperatively	24 hours postoperatively	48 hours postoperatively	72 hours postoperatively
Control group (n=32)	0.91±1.57	0.91±1.75	2.75±1.34	2.25±1.05	2.06±0.62
Observation group (n=32)	1.13±1.69	0.91±1.57	1.38±1.83	1.16±1.44	1.31±1.42
t	0.534	0.000	3.429	3.476	2.732
P	0.595	1.000	0.001	0.001	0.008

2.4 Comparison of Treatment Efficacy, Hospitalization Duration, and Hospitalization Costs Between the Two Groups

The observation group demonstrated superior therapeutic efficacy compared to the control group (P<0.05), with significantly shorter hospital stays and lower hospitalization costs (P<0.05), showing statistically significant differences (see Table 4).

Table4. Comparison of Treatment Efficacy, Hospitalization Duration, and Hospitalization Costs Between the Two Groups

group	treatment effect (n)			Number of hospitalization days (days)	Hospitalization expenses (ten thousand)
	excellence	valid	invalid		
Control group (n=32)	18	12	2	14.69±10.37	3.90±3.14
Observation group (n=32)	27	5	0	9.78±4.13	2.61±1.64
t/2	6.682			2.486	2.063
P	0.035			0.016	0.043

3. Discussion

pathogenic microorganisms can invade subcutaneous tissues and produce various metabolic products like toxins and enzymes.Approximately 40% of these patients might develop concurrent infections, which greatly increases the risk of toe amputation or limb amputation, which severely affects patient prognosis [8].This study used photon therapy and ultrasound-guided drug delivery to treat patients with diabetic foot ulcers.The results demonstrated a significant reduction in antibiotic usage duration in the observation group

(P<0.05).Xu Juan et al. [9] in showed that using photherapy devices to treat infected wound sites of traumatic tissue injuries can reduce the time antimicrobial agent is administered by 40%, and the infection control outcomes are favorable, which aligns with their findings.This effect might be due to the combined effect of photherapy and ultrasonic drug delivery.Photherapy activates mitochondrial cytochrome C oxidase, which promotes ATP synthesis and fibroblast proliferation, thus accelerating collagen deposition and angiogenesis, achieving dual repair at both physical and molecular levels[10].Ultrasonic drug delivery uses cavitation and microfluidic effects of ultrasound to enhance skin permeability and target drug penetration into deep tissues, increase local drug concentration, and synergistically enhance anti-inflammatory and antibacterial effects [11]. Patients with diabetic foot ulcers usually experience severe, multifactorial pain even at rest, because there are multiple factors like neuropathy, vascular disease, local wound inflammation and infection.Persistent pain can activate the hypothalamic-pituitary-adrenal axis, which inhibits endothelial cell proliferation, impairs collagen synthesis, and thus delays wound healing [12]。 Additionally, pain reduces patients' mobility and treatment adherence, which negatively affects sleep quality and psychological well-being, and increases the risk of anxiety and depression.Therefore, effective pain management is a critical component in promoting the recovery of diabetic foot ulcers [13].The results of this study demonstrated that the pain scores in the observation group were significantly lower than those in the control group at 24 hours, 48 hours, and 72 hours postoperatively (P<0.05).The underlying mechanisms are mainly due to two factors.Firstly, the red light in the photherapy device has a specific wavelength, which converts mitochondrial energy absorption by local tissue cells into thermal energy, thereby accelerating local microcirculation, inhibiting the synthesis of prostaglandin E2 (PGE2)), and reducing inflammatory factors like interleukin-6 (IL-6)), which alleviate pain. Moreover, it might have analgesic effects similar to physical therapy by modulating ion channels in neuronal membranes and reducing pain signal transmission.Combined ultrasound drug delivery can further improve local anti-inflammatory effects and synergistically reduce pain, which aligns with the results of Li Huihua et al.[14] This indicates that combing ultrasound and drug delivery is beneficial for wound pain management.

Diabetic foot ulcers have a long disease course, slow healing, and high treatment costs.Patients usually need more hospitalization and continuous medical interventions, which results in a big increase in healthcare resource consumption, and a lot of economic burden on patients' families and the social healthcare system.The results of this study demonstrated that the treatment efficacy in the observation group was superior to that in the control group (P<0.05), with significantly shorter hospital stays and reduced hospitalization costs (P<0.05). These findings indicate that the combination of photon therapy with ultrasound-guided drug deliveryan additional intervention did not increase hospitalization costs while achieving superior therapeutic outcomes.This effect might be due to the photobiomodulatory effects of photon therapy, which enhance cellular synthesis, accelerate wound and ulcer healing, and improve microcirculation, while also combing with ultrasound guided drug delivery to enhance local drug bioavailability, strengthen anti-inflammatory and analgesic effects, and speed up tissue repair, all contributing to improved wound healing.These findings align with Wu Futing et al. [15] study. Results indicate that combing photon therapy with ultrasound-guided drug delivery speeds wound healing, enhances therapeutic effectiveness, shortens hospitalization time, and gives a good cost-effectiveness ratio.

4. Summary

This study compared the efficacy of single-photon therapy versus photon therapy combined with ultrasound-guided drug delivery in diabetic foot ulcers, demonstrating that the combined treatment regimen exhibits significant advantages in promoting wound healing, alleviating pain, reducing antibiotic use, shortening hospital stays, and lowering hospitalization costs. Future multicenter, large-sample randomized controlled trials will be conducted to further investigate the optimal intervention timing and parameter settings for photon therapy combined with ultrasound-guided drug delivery. These findings, integrated with comprehensive management strategies, will establish standardized nursing pathways, providing evidence-based guidelines for precision nursing care of diabetic foot ulcers.

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References

[1] REARDON R, SIMRING D, KIM B, et al. The diabetic foot ulcer[J]. Australian Journal of General Practice, 2020, 49(5): 250-255.
[2] Sun Zuyan, Huang Wenliang, Xu Lin, et al. Accelerated healing of foot ulcers in type 2 diabetes model rabbits with transverse tibial bone grafting: The involvement and regulation of circular RNA [J]. China Tissue Engineering Research, 2026,30(22):5639-5649.
[3] Huang Xiaolian, Ran Qiling, Li Cheng, et al. Clinical efficacy of ultrasound-guided drug delivery in patients with facial swelling and pain after facial trauma or surgery [J]. Integrated Traditional Chinese and Western Medicine Nursing (Chinese-English), 2022,8(11):85-87.
[4] Zhao Yongfeng. Study on the Efficacy of Pulse-Mode Photon Therapy Device in Treating Chronic Refractory Wounds [J]. China Practical Medicine, 2023,18(15):81-84.
[5] Gu Yongquan, Ran Xingwu, Guo Lianrui, et al. China Guidelines for the Diagnosis and Treatment of Diabetic Foot [J]. China Journal of Clinical Physicians, 2024,52(11):1287-1296.
[6] Wang Yuzhen, Jia Chenglin, Zhang Yongkang, et al. Correlation analysis of clinical characteristics between wet and dry gangrene in diabetic foot [J]. China Journal of Orthopedics and Traumatology, 2025,38(09):884-890.
[7] Hu Kaiyan. Clinical efficacy evaluation of sulfadiazine silver cream combined with Jinyintai in the treatment of diabetic foot ulcers [J]. Double Foot and Health Care, 2019,28(06):11-12.
[8] He S, Guo LNY, Yan J, et al. Mechanisms of diabetic foot infections and the monitoring value of serum procalcitonin [J]. Physician Online, 2025,15(2):91-95.
[9] Xu Juan, Liu Xijie, Liu Fang, et al. Clinical efficacy of phototherapy device in treating postoperative infections after repair of hand trauma with perforating skin flaps [J]. Chinese Journal of Infectious Diseases in Hospitals, 2023,33(10):1526-1529.
[10] BROCCO E, CURCI V, DA ROS R, BROCCO E, CURCI V, DA ROS R, et al. Photodynamic Topical Antimicrobial Therapy for Infected Diabetic Foot Ulcers in Patients With Diabetes: A Case Series[J]. The International Journal of Lower Extremity Wounds, 2022, 21(2): 137-140.
[11] Xu Yue. Clinical Study on the Combined Use of Qi-Regulating and Blood-Activating Formula with Ultrasound Drug Delivery for Tumoroid Goiter of Phlegm-Phlebitis and Blood Stasis Type [D]. Zhejiang University of Chinese Medicine, 2024. DOI: 10.27465/d.cnki.gzzyc. 2024.000622.
[12] Wang Qian, Zhu Hongjuan, Feng Ying, et al. Cross-sectional survey and factor analysis of pain status in patients with diabetic foot ulcers [J]. Chinese Journal of Burn and Wound Care, 2023,39(4):330-336.
[13] Xu Liangqin, Liu Kang. Observation on the therapeutic efficacy of short-wave combined with ultrasound drug penetration therapy in patients with ankle sprain [J]. Reflex Therapy and Rehabilitation Medicine, 2024,5(05):54-56+60.
[14] Li Huihua, Zhao Wei. Clinical efficacy of ultrasound iontophoresis therapy for the acute phase of sciatica [J]. Journal of Clinical Rational Drug Use, 2022,15(14):176-177+181.
[15] Wu Futong, Wu Yilin, Wang Fang. Clinical study on modified Shenling Baizhu Powder combined with Xiaoxun Decoction for ultrasound-guided drug penetration therapy in patients with spleen deficiency and dampness excess type colonic polyps after endoscopic resection [J]. New Traditional Chinese Medicine, 2025,57(21):25-30.

